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Scoring General Science Text and Course

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Since the status of general science is not so definitely settled as is that of English, special sciences, and other well established courses in our schools, it is more difficult to make a score card for a general science text and course. It is hoped that the reader will take this into consideration when looking over the following score cards, which are only intended to be suggestive of some of the outstanding essentials of a general science text and course of study.

SCORE CARD FOR GENERAL SCIENCE TEXT

1. Problem method 15
2. Problems that meet the interests and needs of pupils 30
   - a. *Do problems help pupil fit into his environment?*
   - b. *Correlation with home economics, agriculture, industrial problems, etc.*
   - c. *Present problems in interesting manner.*
   - d. *Consider relative value of problems selected.*
3. Abundant descriptive material to solve problems 10
   - a. *Text should not contain short sketches of innumerable topics.*
4. Special sciences subordinate and indistinguishable in solving problems 15
   - a. *One or two sciences should not play major part in text.*
5. Mechanical devices 20
   - a. *Table of contents with a comprehensive outline of text.*
   - b. *Glossary with important definitions.*
   - c. *Index and appendix with key to laws, facts and other necessary data made easily accessible to pupils.*
   - d. *Attractiveness of arrangement.*
   - e. *Legibility of print.*
6. Illustrations 5
   - a. *Attractive and interesting.*
   - b. *Should supplement and contribute to discussion.*
7. Comprehension 5
   - a. *Not too elementary nor too advanced.*

100

DISCUSSION OF THE SCORE CARD

1. *The problem method.*

The arranging of subject matter about a central idea which is stated in the form of a problem has the following advantages:

1. Eliminates useless subject matter.
2. Places emphasis on important points.
3. Links the subject with children's interests.
4. Motivates work.
5. Gives definiteness.
6. Promotes thinking.

The average text is organized by topics which often do not appeal to the student except as a lesson that must be learned. By stating these topics so the central idea forms a problem connected with some concrete phase of the world's activities, interest is at once aroused. To illustrate: which of the following will arouse most interest—a chapter on "Photosynthesis" or the study of "How Plants get their Food?"

2 and 3. *Problems that meet the interests and needs of the everyday life of the pupil, with abundant descriptive material to solve each problem.*

That problems must meet the needs of the pupils is an axiom in educational methods of today. General science more than any science course given in our schools today must give pupils an understanding of the fundamental laws which govern their lives, because the majority of those pupils get no other scientific education. As time is so limited and since general science includes such a broad field it is imperative that only the problems with the most important scientific principles be included in the text book. By eliminating a great number of the topics of lesser importance, space could be devoted to abundant descriptive material for the major problems of general science. Here Nature's laws could appear in dissimilar circumstances and in increasing complexity—as is true of life—giving a far more complete understanding of natural phenomena than is possible in the elementary sketchy outlines that predominate today.

In meeting the needs of the pupils, there arises the problem of correlating general science with industry, home economics and agriculture. It is very difficult for a single text to correlate general science with these important fields. There are two possible ways of meeting the situation; *first*, a text written for each of these fields or *second*, the more important problems could be carefully worked out separately in pamphlet form by those familiar with the several sciences used in their solution and these pamphlets used in addition to the text. Some such method is sorely needed to make general science function in relation to these great fields.

4. *Special sciences subordinate and indistinguishable in the solving of problems.*

That the special sciences should be subordinated and used only as needed in the solution of a problem is obvious. A general science text in which chemistry or physics or botany or any special science plays the leading role is not truly a *general* science text. It is not difficult to take the average general science text on the market today and determine whether the writer is a chemist, a physicist or botanist or what, by the emphasis he places on these fields of science. Each scientist feels that his science explains all life and tho it is well to be loyal to one's profession, still it is unfortunate to have the author write a chemistry or botany text and label it "General Science."

It is practically impossible for a special science man to avoid featuring his special science in a text he may write because he is so highly trained in his particular field that all others have necessarily been largely excluded. Try as he may he cannot get away from his specialized past training long enough to write a text on general science.

The remaining points on the score card need no further explanation than that given in the subheads.

SCORE CARD FOR GENERAL SCIENCE COURSE

1.	Use of problem method	10
2.	Psychological approach to problems	10
3.	Does course through continued emphasis develop ability to consider data and reason through to an unprejudiced conclusion?	10
4.	Do problems appeal to community interests and activities of the pupils?	10
5.	Is experiment and practical work required by pupils?	10
6.	Are everyday experiences of pupils used as a source of data?	10
7.	Are magazines, bulletins, and scientific books other than text used?	5
8.	Does the course give information of greatest relative value? Does it help student to understand life and natural phenomena?	10
9.	Is science used to explain natural phenomena and not used as an end in itself	10
10.	Is pupil's appreciation of evironment and natural phenomena developed?	10
11.	Are problems arranged according to seasonal sequence?	5
		100

The general science course is dependent primarily upon the training and ability of the teacher. The aim of the course itself, with all it may accomplish is the result of the efforts of the teacher. The general science teacher must have not only all the qualifications of other teachers but must have in addition to that a scientific, eg., an investigating, inquiring, unprejudiced mind that can observe data and put them in relation to one another. One of the chief considerations in a general science course is, "Does the course, through continued emphasis, develop ability to consider data and reason through to an unprejudiced conclusion?" It is obvious that unless the teacher is capable of doing this, that the pupils taking the course will not be so trained. The development of independent thought, clear reasoning and good judgment—all essential to scientific training—can only be developed in others by one so talented.

One test of a good general science teacher is the ability to use the psychological method of approach. While the logical method has its use, it should be remembered that the most effective way to get general science over to the pupil is to start with his experiences, however crude, and use these in building essential scientific principles and in giving scientific training. Using homely experiences of his everyday life enlists his natural interests and makes his entire attention to general science spontaneous.

That general science will be unsatisfactory where taught in the logical—cut and dried—text book fashion is certain. It is equally true that general science can be made one of the most valuable courses given in our secondary schools when taught by a person who is in sympathy with the course, has a scientific training and is capable of using the everyday experiences of the pupils to interest them in the work and as a basis for building scientific principles.

The Reorganization of Science in the Secondary Schools of Great Britain and America[1]

(Two important reports of interest to administrators and teachers.)

Earl R. Glenn, The Lincoln School of Teachers College, Columbia University.

OUTLINE

I. Science in the secondary schools of Great Britain.
   - A. Science in the secondary school
   - B. Science course, ages 12 to 15
   - C. Science course, ages 16 to 18

II. Science in the secondary schools of America.
   - A. Science as a whole in secondary education
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     4. Small high school
   - D. The principal courses in science
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I. SCIENCE IN THE SECONDARY SCHOOLS OF GREAT BRITAIN

Those who desire to make science function in the education of pupils of high school age will find many valuable suggestions in two recent reports dealing with the reorganization of science in secondary schools.

The first report[1], which was published more than two years ago but has received almost no attention in American journals, is entitled, "Natural Science in Education," and is a report

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[1]Thomson, Sir J. J., and Committee, Natural Science in Education, His Majesty's Stationery Office, London. Price 15, 6d.

of the Committee on Natural Science in the Educational System of Great Britain. This committee was appointed by the Prime Minister in August, 1916, and issued its report in 1918. Sir J. J. Thomson, who is well known for his great discoveries in physics, as well as for his interest in public affairs, was chairman of the committee which was appointed to advise what measures are needed to promote the study of science with respect to the needs of a liberal education, to the advancement of pure science, and to the development of the trades, industries, and professions which depend upon applied science.

The final report is a volume consisting of 272 pages which represents the labor of many able men and women. The importance of this report has been appreciated by the United States Bureau of Education and almost the entire report[2] has been reprinted by the Government Printing Office.

We quote a few statements from the "Summary of Principal Conclusions" (Chapter VI, pages 237-8).

A. Science in the Secondary Schools.

"Steps should be taken to secure for all pupils in state-aided secondary schools a school life beginning not later than 12 and extending at least to 16.

"In all secondary schools for boys, the time given to science should be not less than 4 periods in the first year from 12 to 16, and not less than 6 periods in the three succeeding years.

"Increased attention should be given to the teaching of science in girls' schools.

"In girls' school with a 24-hour school week not less than 3 hours per week should be devoted to science in the period 12-16."

B. Science Course, ages 12 to 15.

"The science work for pupils under 16 should be planned as a self-contained course, and should include besides physics and chemistry, some study of plant and animal life.

"More attention should be directed to those aspects of the sciences which bear directly on the objects and experiences of every day life.

"There should be as close correlation as possible between the teaching of mathematics and science at all stages in school work."

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[2]Natural Science Teaching in Great Britain, Bulletin 1919, No. 63. Government Printing Office, Washington, D. C. Price 15 cents.

C. Science Course, ages 16 to 18.

"The amount of time devoted from 16 to 18 to the subject or subjects in which a pupil is specializing should be not less than one-half or more than two-thirds of the school week.

"Those specializing in science should continue some literary study, and those specializing in literary subjects should give some time to science work of an appropriate kind.

"Pupils who do advanced work in science should be enabled to acquire a reading knowledge of French and German."

II. SCIENCE IN THE SECONDARY SCHOOLS OF AMERICA.

The second report[3] to which we wish to refer is a more recent publication entitled "Reorganization of Science in Secondary Schools." This Bulletin is one of the reports issued by the Commission on the Reorganization of Secondary Education. This American report was prepared by a science committee of 47 members with Professor Otis W. Caldwell of Teachers College, Columbia University, as Chairman. The work of this committee has been in progress for seven years and now that the report has been approved by the Reviewing Committee of the Commission on the Reorganization of Secondary Education, the report is issued for public distribution.

A. Science as a Whole in Secondary Education.

The report states that there is great need for reorganizing the science courses of the secondary schools because of:

1. The variation of purposes for which the sciences are taught.
2. The increasing number of sciences offered.
3. The development of intensive specialization within the sciences.
4. The lack of sequence in the order of teaching the various sciences.
5. The wide variation in content and method.

B. Contribution of Science in General Education.

The Committee suggests that science instruction should contribute to six chief objectives in general education as follows:

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[3]Caldwell, Otis W., and Committee, Reorganization of Science in Secondary Schools, Bulletin 1920, No. 26. Government Printing Office, Washington, D. C. Price 10 cents.

1. *Health*: Topics dealing with health should be taught in the junior high school, and in at least the first and second years of the four year high school.
2. *Worthy home membership*: The conveniences that make the modern home comfortable and attractive require science for their full appreciation and intelligent use.
3. *Vocation*: Science should be so presented as to be of direct assistance in the wise selection of vocation.
4. *Citizenship*: Students should acquire a more intelligent appreciation of the services rendered by the scientist and technologist.
5. *Use of leisure time*: Science should be taught so as to suggest useful and pleasurable avocations.
6. *Ethical character*: The science course should contribute to an adequate conception of truth and a working confidence in the laws of cause and effect.

C. Science Sequences Recommended

1. Junior-senior high school.

Seventh year: General science, hygiene included, three periods per week.

Eighth year: General science, hygiene included, three periods per week.

Note: In case general science is not carried through seventh and eighth grades it may be given five periods per week.

Ninth year: Biology, including hygiene. Courses may consist of general biology, botany, or zoology.

Tenth year, eleventh year, twelfth year: Elective courses as follows:

a. Chemistry—General chemistry and special courses.
b. Physics—General physics and special courses.
c. General geography, or physiography.
d. Advanced biological science.

2. Large four year high school

First year: General science, including hygiene.

Second year: Biology, including hygiene. Courses may consist of general biology, botany, or zoology.

Third year, fourth year: Elective courses as follows:

a. Chemistry b. Physics
c. General geography or physiography
d. Advanced biological sciences.

3. Four year high school of medium size.
   First year: General science.
   Second year: Biology.
   Third year: Chemistry.
   Fourth year: Physics.
4. Small high school.
   First year: General science.
   Second year: Biology.
   Third year, fourth year: Chemistry and physics. It is desirable to alternate the courses in chemistry and physics in alternate years.

D. The Principal Courses in Science.

Part II of the reports concerns the details of the principal courses in science, namely: general science, biology, chemistry, and physics. Several pages are devoted to each science in discussing the selection and organization of subject matter, methods of teaching, type topics, aims, excursions, etc.

E. The Science Teacher.

At the end of the report, there is a brief appendix dealing with the science teacher, his training, and professional development.

F. Defects in American Education; Remedies for them.

In discussing the defects in American education[4], a well known educator mentions:

1. Bad diet.
2. Infant mortality.
3. Feeble efforts of state and nation in combating tuberculosis.
4. Popular ignorance of venereal diseases.
5. Lack of manual skill.
6. Little training of the senses.
7. No habitual accuracy of observation or statement.

Finally, for the first time in the history of high school science, we have two reports issued by independent committees of two great nations, in which practically the same science program is advocated for the secondary schools of the respective nations. If the suggestions of these committees could be put into intelligent operation at once, the defects mentioned above might be remedied in an effective manner in a reasonable length of time.

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[4]Eliot, Charles W., Certain defects in American education and the remedies for them. Teachers Leaflet, No. 5, Bureau of Education, Washington, D. C.

Studies of the Masters—VI. Galileo

By JOHN F. WOODHULL

"Truth forever on the scaffold,
Wrong forever on the throne".

Galileo is generally rated as one of the half dozen greatest men our race has produced. He saw the truth more clearly than any other man of his time and he tried with missionary zeal to bring others to a knowledge of it. For his devotion to truth he suffered worse than death, and the tide of willful and wicked ignorance among his countrymen which overwhelmed him was not turned backward for more than a century after his death.

At twenty-five years of age, Galileo was a professor in the faculty of the University of Pisa. He was even then called "the Archimedes of his time." His associates on the faculty belonged to the class called *transcendentalists.* Transcendentalists, according to Webster, are persons who speculate on what lies beyond the reach of the human intellect, on things which are fantastic, vague, and illusive. Galileo, on the other hand was an empiricist. That is: one who engages in the pursuit of knowledge by observation and experiment. He placed reliance upon practical experience, while the other members of the faculty trusted only to authority; chiefly the authority of Aristotle. "To the narrow conceptions of the times, a philosopher needed only to *know* Aristotle by heart; to *understand* him was a secondary consideration; to contradict him was a blasphemy." The other members of the faculty said "An iron ball weighing one hundred pounds will fall through a space of one hundred yards while a weight of one pound is falling through a space of one yard." They said this because Aristotle had said it. Galileo doubted it and, tired of their interminable discussions, tried the experiment at the leaning tower of Pisa in the presence of a multitude, and proved that two such weights would fall through the whole 179 feet side by side and strike the earth together. This, however, did not convince his adversaries who began that bitter persecution, which continued throughout his life.

Galileo's method of dealing with his opponents is well illustrated by the following incident given in his own words:

"I cannot refrain from marvelling that Sarsi will persist in proving to me, by authorities, that which at any moment I can bring to the test of experiment. . . . . Sarsi insists that I must believe, on Suidas's credit, that the Babylonians cooked eggs by swiftly whirling them in a sling. Now we have eggs, and slings, and strong men to whirl them, and yet they will not become cooked; nay, if they were hot at first they more quickly become cold; and since nothing is wanted to us but to be Babylonians, it follows that being Babylonians is the true cause why eggs become cooked and not the friction of the air. Is it possible that in travelling, Sarsi has never noticed what freshness is occasioned on the face by the continual change of air? And if he has felt it, will he rather trust the relation by others of what was done two thousand years ago at Babylon, than what he can at this moment verify in his own person? I at least will not be so willfully wrong, and so ungrateful to nature and to God, that having been gifted with sense and language I should voluntarily set less value on such great endowments than on the fallacies of a fellow-man, and blindly and blunderingly believe whatever I hear, and barter the freedom of my intellect for slavery to one as liable to error as myself."

Poincare writing on "The Value of Science" says: "Our remote ancestors were creatures of superstition, startled at every display of incomprehensible forces, accustomed to attribute all natural phenomena to the caprice of good and evil spirits. The basis of scientific progress is law. Recognizing, as we do, the unchangeable basis of these laws, we do not foolishly demand that they be changed, but submit ourselves to them, and utilize them to the advantage of mankind."

Galileo smashed into fragments the medieval mode of thought and introduced the modern method of Science. At what period of the world's history did this occur?

He was born in 1564, the same year that Shakespeare was born, and the year that Calvin and Michael Angelo died, and he died in 1642, the year that Isaac Newton was born. His birth occured in the sixth year of the reign of Queen Elizabeth of England, and four years after the birth of Francis Bacon.

Leonardo da Vinci, Raphael, Albrecht Durer, Correggio, Savanarola, Paracelsus, Copernicus, Thomas Cranmer, Ignatius Loyola, Martin Luther, Erasmus and Melanchthon had

preceded him by about a generation, and all had done something to prepare the way.

Palestrina, Titian, Rubens, Van Dyke, Rembrandt, Gustavus Adolphus, John Bunyan, Huyghens, Tycho Brahe, Kepler, Gilbert, Boyle, Glauber, Harvey, Pascal, von Guericke, Descartes, Oliver Cromwell, and John Milton were contemporaries.

During his life time occured the thirty years war in Europe; the execution of Mary Stuart; the defeat of the Spanish Armada; the gunpowder plot; the settlement of St. Augustine in Florida; the settlement of Jamestown in Virginia; the landing of the Pilgrims in America; the exploration of the Hudson river by Henry Hudson; the founding of Harvard College; the publication of Bacon's Novum Organum; the Massacre of St. Bartholomew and the burning of Bruno by the Inquisition at Rome.

Soon after his death, Charles the First of England was beheaded. The Great Plague and the Great Fire occured in London. Stahl enunciated the phlogistic theory. The Royal Society of England and the French Institute were founded. An era of invention opened and progress began to be much more rapid.

It is often said that real science is only about three hundred years old; that it had its birth during the Renaissance, which period is conceived of as something more than a "rebirth."

It would be more correct, however, to say that, although science has had a phenominal growth during these latter years, there have been a few high lights of science in every age. Science by the experimental and inductive method has been the chief concern of certain men in every age since the beginning of the race. Thales (650? B. C.), Anaximander (611-547 B. C.), Pythagoras (532 B. C.), Anaxagoras (500-428 B. C.), Aristarchus (300? B. C.), Archimedes (287-212 B. C.), Eratosthenes (276 B. C.), and Hipparchus (160? B. C.) were all masters of science. And these men, by the methods of modern research, learned most of the facts which are embedded in the Copernican System; viz, that the north star is the only body in the sky which has no apparent motion; that the phases of the moon are due to the fact that it revolves about the earth and shines by reflected sunlight; that the earth is round and

that it rotates on its axis producing thereby day and night; that the earth, moon, and planets revolve about the sun; that Venus and Mercury must exhibit phases like the moon; that eclipses of the moon are caused by the earth's passing between it and the sun, casting its shadow upon the moon, and that eclipses of the sun are caused by the moon passing between the earth and the sun, thus cutting off some or all of the sun's light from the earth. The distance around the earth was measured as we measure it now. The fact that they made it 31,000 miles while we make it 25,000 means merely that we have improved instruments with which to make the measurements.

The Copernican System was fully established 1800 years before Copernicus lived. Yet for this long established truth Copernicus escaped being a martyr only by dying prematurely. Of Copernicus Sir Oliver Lodge writes: "An earnest, patient, and God-fearing man, a deep student, and unbiased thinker,—to him it was given to effect such a revolution in the whole course of man's thoughts as is difficult to parallel." "A system (the Ptolamaic) venerable with age, and supported by great names, was universally believed, and had been believed for centuries. To doubt this system, and to seek another and better one, at a time when all men's minds were governed by tradition and authority, and when to doubt was sin—this required a great mind and such a character had this monk of Frauenburg." He escaped a martyr's death by dying in 1543. For this truth, and some others now firmly established, Bruno was burned to death in 1600. For this truth also Galileo would certainly have been put to death in 1633 if there had been enough life left in him to extinguish.

"Truth forever on the scaffold, wrong forever on the throne."

Galileo, like Newton, Maxwell, and most other masters of science, showed in early life a deep interest in things mechanical. And, like very many other masters in science, he showed skill in music, drawing and painting. He was a poet, a playwright, and a literary genius. Like most masters of science he was no specialist. "There was no art, science, nor handicraft in which he was not superior to the generality of men professing them." On account of his questioning and controversial spirit he was called "The Wrangler" when a stu-

dent, though he found logic a futile and distasteful study. He admired the Greeks because they did not study ancient languages, and because they got most of their mathematics from music and dancing. The guiding principle of Galileo's life is well expressed in Milton's words in Paradise Lost: "to know that which before us lies in daily life is the prime wisdom."

He was an eighteen year old student at the University of Pisa, when, "praying one day in the cathedral like a good catholic as he was all his life," his attention was directed to the swinging of the lamp which was suspended from the dome. In spite of the fact that the distance through which the lamp moved grew constantly shorter he found that the time taken for each swing remained the same. It was equal to about five beats of his pulse. He had never studied mathematics in the schools, but from this observation he not only deduced the laws of the pendulum, hitherto unknown, but he forthwith invented an instrument utilizing the pendulum for measuring time. It was called the pulsilogia and was soon used by physicians all over Europe for timing the pulse of patients. This was before the days of clocks and watches. Like Agassiz, Galileo thought that facts are stupid things until applied. He studied—excurricular—the works of Archimedes whom he always called his master.

Why were there no inventors during the eighteen hundred years between Archimedes and Galileo? (B. C. 212 to 1564 A. D.)

He left the University as student at 21 years of age without getting his degree. But returned at 25 years of age as professor. In this capacity he received an annual salary of $65. At least one of his colleagues on the faculty received a salary of $2,167. This ratio of science to "humanities" has been increased somewhat during the last three centuries, but there still remain some schools where the teachers of pure science receive $1,000 while those of Latin receive $3,000.

Whatever label his chair at Pisa may have had, he made it his chief business to question the conclusions of Aristotle by experiments, which he performed for the benefit of all. He gathered the multitude about the base of the leaning tower of Pisa while he dropped the weights which proved that Aristotle was wrong regarding the laws of falling bodies. He did yeo-

man service in this sort of campaign for nearly three years, convincing all but the hide bound. Sir David Brewster says he was contemptuous of ancient dogma, defiant of authority, obnoxious to learned dunces and narrow pedants and treadmill professors and bigoted priests. The Aristotelian professors, the temporizing Jesuits, the political churchmen and that timid but respectable body who at all times dread innovation entered into an alliance against the philosophical tyrant who threatened them with the penalties of knowledge. They boycotted and calumniated him. They drove him from Pisa.

Long afterward a pupil of his wrote "From Signor Galileo, professor at Pisa, I learned more in the three months than I did in as many years from other men. I thank God for having given me for a master the greatest man the world has ever seen."

Galileo left Pisa in disgust and showed his contempt by writing a play ridiculing the University ordinance compelling professors to wear academic gowns not only when lecturing, but when calling on friends, etc. He went immediately to the University of Padua as professor on three times his former salary. In this position he remained eighteen years during which time his salary was increased six fold. Galileo's reputation as a teacher was now widely spread over Europe, and numbers of foreigners flocked to Padua to attend his lectures. Among these were the Archduke Ferdinand, afterwards Emperor of Germany; the Landgrave of Hesse; the Princes of Alsace and Mantua; Prince Gustavus of Sweden; William Harvey, the discoverer of the circulation of the blood, and many others. His lecture room was capable of seating 1,000 persons and this was at times overcrowded so that he had to adjourn to the open air. He finally had assigned to him a lecture room capable of seating 2,000. He had the habit of drawing upon the experiences of daily life for illustrations in his lectures, thus leading his hearers to see that their own lives furnished a continual opportunity for the study of physical science. During his stay at Padua he invented the thermometer, the telescope, the microscope, and many other ingenious devices. The fact that others also invented some of them makes no difference. Most inventions are made independently by several different persons. If human beings were properly instructed,

each invention would be made independently by hundreds of different persons and inventions would occur a hundred fold more rapidly than now.

Galileo ground his own lenses. There was no other way to get them. The highest magnifying power which he reached was 30 diameters or about 1,000 times in area. He made a hundred or more telescopes which were distributed over Italy, France, Germany, etc. In this way he hoped to accomplish the greatest desire of his life, the universal knowledge of, and acceptance of the Copernican doctrine.

[How he enthroned truth and tore down its scaffold will appear in our next issue.]

Civic Science: General Science for the Junior High School [1]

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A Changing Point of View: Whether or not we can detect the fact that education is in process of change at the present time, whether or not we are teaching science exactly as we did six years ago we all realize that the child of tomorrow will receive a vastly different type of education from that received by the child of yesterday. The change is coming and in response to the insistent demand so long heard, to make education more practical. The turmoil of the World War has given us a point of view. It has loosened the props of the old conservative type of education, and makes it possible to build anew, to try out different material and to try it in different ways.

Twenty years ago, yes, ten years ago, general science was fighting for its very existence. Now it has won its fight and is as firmly established as any special science. In the hands of its promoters it has been a live-wire and has challenged the pupil to his best effort. The subject has, however, had more than a healthy growth. It is an overgrown child

[1] Abstract of paper given at General Science Section meeting of the Central Association of Mathematics and Science Teachers in Chicago, Nov. 26, 1920.

as it were. And as a result we find much "General Science" which lacks the vital contact points of life which are essential to a healthy growth. Many of our textbooks merely give information where they should stimulate activity. Our best teachers, either with or without text books, are able to secure pupil activity which is of far greater value than the facts derived from a text. We need more suggestions of ways and means whereby the average teacher can secure keen interest on the part of the pupil which carries over into self-imposed activity.

Science Problems Increasing: Problems involving a knowledge of natural laws have perplexed the human race since the time of primitive man, and because man has solved so many of these problems and sought new problems the race has constantly advanced in civilization. These very advances in knowledge and application of natural law have brought more problems and more difficult problems for us of today to solve. Science problems in the home, in the community and in the nation increase with tremendous rapidity. Some of these require all the concentration of our trained experts, others are within the range of the twelve year old boy or girl.

One hundred years ago, the problem of how to heat the house was comparatively simple and it was solved by having ample fireplaces and plenty of wood. Today we may choose between using fuels and electricity. If we choose fuels, then which one shall we choose, wood, coal, peat, coke, oil, or gas? The kind of fuel determines the kind of device in which to burn it and so, one problem leads to another and this in turn to still another.

Even fifty years ago, the world was without such essential conveniences as the telephone, the automobile, wireless telegraphy, X-ray, gas engines, vacuum cleaners, typewriters, moving pictures, electric cars, incandescent electric lights, gas mantles, gas stoves, safety matches, airplanes, asphalt pavings, and a hundred other useful everyday devices. The addition of so many intricate scientific devices to the environment of man demanding as they do an intelligent use has surrounded him with a multitude of science problems which our grandfathers never had.

Forty years ago the lighting problem was simple. Candles and oil were the only choice. Today, we may still use candle or oil but we also have added to our list from which to choose illluminating gas, acetylene, electric lights of various types, and gasoline and alcohol lamps using mantles. It doubtless seems to many that such problems as we have today with lighting are very simple and required no school time devoted to them. This is the very crux of the matter in many of our science problems. They seem too simple to solve so instead of solving them people deceive themselves and continue in the old ruts. Make a survey of the homes in your town, find out how many are today using gas without mantles for lighting and the old current-wasting carbon electric lamps instead of tungsten and you will realize the need of bringing live science problems into these homes and you will understand how practical science teaching may be. We can show the children how the bare gas flame and the carbon lamp not only waste our money but also rapidly decreased our available national energy because the supply of fuel from which our lights are obtained is limited. Find out how many pupils read at home with improper light. The problem of safeguarding our pupils' eyes requires more of our attention.

Civic Science Problems: The science problems which arise in one's environment have to do with the relationship of people who make up a community. That is, they deal with citizenship, or they may be called civic problems. They may deal with health, saving life, saving property, conservation of natural resources, welfare work, and various other problems of general public interest.

A large part of our population is now grouped into communities of varying sizes. As a result of this we have in addition to the individual and home-group problems the community-group problems. Many of these are merely enlarged home problems, while others are strictly problems belonging alone to the community.

The following list of questions is copied from the Canadian Public Health Journal:

1. Do you know the birth rate and the death rate in your community, and whether it compares favorably or unfavorably with that in other places?

2. Have you a welfare or health council to supplement and stimulate the work of your local health department? Has such a council made a survey of health conditions from the point of view of prevention rather than cure, and have its constructive recommendations borne fruit as seen in a higher standard of community health?

3. Do you know what diseases are most prevalent in your community and what measures are taken against them?

4. Is there good medical inspection in your schools by doctors and nurses, with follow-up work when necessary in homes? What published reports have you from these inspectors? Is your health department sufficiently financed to do this work in a thorough and efficient manner?

5. Have any of the schools in your town made provisions for providing lunch—free or at a nominal price—for the children?

6. Have you adequate hospital and dispensary accommodation with ample provision for free treatment?

7. What health standards are guaranteed in your jails, insane asylums, children's homes, homes for the aged and other institutions, guaranteed for these dependent delinquents and defectives, by a society that is so largely responsible, through ignorance, indifference or neglect, for having these wards of the state dependent on its intelligent, sympathetic care and generosity?

How many average citizens can answer these questions?

There is no denying the need of better health teaching. Our army examinations indicated the woeful lack of physically fit men in the country. Surveys made show the lack of definite health teaching in a surprisingly large number of schools. Many superintendents have advocated the union of hygiene and science, believing that when taught with the science background and with the fuller *understanding of the reasons why* that science can give it, hygiene instruction will make a greater impression upon the child and will, therefore, produce a much more lasting effect for good and will help in some measure toward greater physical fitness in our boys and girls.

It is not merely the personal health habit we wish to establish, but a sense of community health rights. If we can so impress the boys and girls with their responsibility toward others and secure good health habits about spreading disease a big thing will have been accomplished. We must not stop short of pointing out the reciprocal relation of the individual and his community. Not only does the individual owe much to the community and must even yield his liberty and endure quarantine if need be, but the community itself owes the individual certain protection against disease and epidemics of disease. This whole question of personal and community hygiene and sanitation is loaded with project-problems, some

of which are these; personal care of one's body, home sanitation, removal of wastes, hygienic heating, ventilating, lighting, pure food supplies, pure water, board of health activities, recreation opportunities—public parks, playgrounds, and baths.

We realize today, perhaps better than ever before, that all our teaching ought to develop those sterling qualities of boyhood and girlhood which are assets in good citizenship. General science is one subject which is particularly fortunate in having a wealth of material which is essential in the consideration of a large number of civic problems. General science thus has a splendid opportunity to participate in the education of pupils, to make a body of citizens who will be more intelligent about the affairs of the city or town and who will be interested in civic betterment. In a similar way general science may help in producing well-informed, rational thinking citizens of the nation.

What better incentive can you hold before your pupils than that they become active factors in making their home towns as nearly perfect as possible and in making each community approach ideal conditions as well? Begin with the home, pass on to the community and then to the outside world with its varied industries by which our nation exists. Science applied to the home, to the community, and then to our national life, if made so practical that real contracts exist between the classroom, the home and the community, and if these contracts are so vital that a better understanding of civic affairs and some real improvements result, then the study of science is making a distinct contribution to society. Sooner or later our school subjects are to be given the acid test. To withstand this test they must begin now to qualify. If the science taught in your school does not touch every day life in a very vital way it does not meet the great needs of the pupil and of society, and it cannot long endure.

The Plan for Civic Science.—The plan for teaching Civic Science is both psychological and logical. It begins with science nearest the pupil—in the home and expands to larger surrounding environments. Since boys and girls of eleven to thirteen years of age spend the greater part of their time at home and are more familiar with the home environment than with any other, it is best for them

as beginners in general science to make the home the center of their study. From our adult point of view we know that science in the home covers small areas of a large number of special sciences and we are pretty well agreed that there should be no attempt to classify the science knowledge as belonging in special groups in the early years of science study. In nature study and geography pupils have already made a beginning in science. They can make use of this science knowledge and their experience now in applying them to the home. Even the sciences related to the home would lead far into remote fields of science were we to allow it to continue without restrictions. It will be better to set limits and to leave many questions and problems, particularly the difficult ones, to be taken up in some future study of science.

Let us draw a circle about the central point where we start our science. This area represents the field of home science, the field within this circle comprises the various home problems which involve a little of each of the different divisions of science. The circumference of the home circle is roughly the boundary line for the general science of the first year. The boundary need not be one that can never be crossed. Frequent excursions may be made across it, but it must be borne in mind that time forbids long excursions if we would consider even briefly the simple science problems of the home.

The most natural field to enter for a second year of science is the larger environment which surrounds the home and of which the home is a part, namely, the community. The home environment is rich in material of natural interest to children but it is mainly in dealing with the science problems of the community that we touch affairs of citizenship and civic responsibilities. Draw another circle outside the home circle. This is to represent the community. Many of the same problems of the home appear here as community problems and here again we must set up barriers beyond which we cannot go very far if we give attention to the various important science questions of the community.

Outside the community we may make still another circle to include a science field still more remote from the pupil's environment, but involving science which is important for all American citizens to know. This field will deal with national

science problems, with the science work carried on by the government and the science underlying the basic industries of the country. A portion of the time during this third year of general science may well be used to give the pupil an introduction to the special sciences and to see the advantages, both of a general science study and of further special science study.

GENERAL SCIENCE IN THE JUNIOR HIGH SCHOOL

A brief outline suggesting the organization of each year of the General Science study indicates much of the subject matter which may be used.

Home Science.—The home environment—its natural resources—whether the conditions are favorable or unfavorable to an ideal home, may serve as an introduction. The biggest asset in life is good health, hence, no subject is more worthy

of a place in our science course than this. In considering good health, we must discuss pure air, water, foods, household pests, germs, and the removal of waste from the home. Heat and light not only are closely related to our health, but to our comfort as well. Not only should fuels and heating methods —useful applications of heat—be considered, but non-useful heat—fires and fire hazards—should be given particular attention in an effort to reduce the fire loss, which in 1919 reached the appalling figure of $325,000,000 in the United States. It is important for children to understand more about their eyes, good and bad practices, and of the sources and use of both natural and artificial light. Let us try to cultivate an aesthetic taste in our pupils by having them observe different homes with their different decorations. Make application of landscape gardening to the home grounds. Consider the home garden with its friends and its enemies, and as "All work and no play makes Jack a dull boy" let us give some attention both to in-door and out-door recreations.

Community Science.—With a little imagination an ideal community can be described and comparisons made between the real and ideal communities. What natural resources has the community? Are they utilized? Weather and climate control man's activity. Apply this control to the local community. Water has an important part in every community, it may be for power production, food production, or domestic and industrial uses. How are we insured against impure and adulterated foods? The community, through its governing body, is under obligation to each citizen in working for good health, in removing waste and in safe-guarding the life and property of the people. Transportation problems involve different types of roads, for different kinds of traffic, the horse, auto, trolley and trains. The automobile and locomotive are today rivals for the child's interest. As essential parts of the working processes of these devices, the steam engine and gasolene engine are studied. Further transportation study must include travel through water by submarine and through the air by air-craft of various types. Modern means of communication are the nerves of a community and make for greater efficiency. Among the most important problems to consider in regard to living things are those dealing with man's im-

proving plants and animals on the earth, and particularly with the progress made by the human race.

Industrial Science.—Mr. Richardson told us this morning that "that nation which makes the closest connection between science and its industries, will be the foremost nation of the world." This name, industrial science, is applied to this third year of study since the major part of the work will in some way relate to our national industries and industrial life. What departments of the state government and national government involve science—as Bureau of Standards, board of health, fire marshal's office, forestry, water commissioner, etc.? What state laws relate to the health of industrial workers in factories and in their homes? What various lines of work are carried on by the United States Department of Agriculture and by the state departments? What is the Smithsonian Institution—its work? What are some of the leading science organizations of the country, and institutions specializing in science education? What are the natural resources problems? What raw materials are used in our basic industries? The processes involved in their use and the science essential to a simple explanation of the processes may be given. This industrial list may include agriculture, steel, fuels, building materials chemical products, electrical appliances and many others. Such aids as irrigation projects, water power and reclamation of land will receive additional attention. Some time should be given to the work of the prominent American scientists, both living and dead, and to a few of the world-renowned scientists abroad.

A brief survey of the science knowledge of the class may now be undertaken and the value of classifying this knowledge into separate compartments or special sciences may be shown. This work may include enough of the fundamentals of biology, physics, chemistry, astronomy and earth science to serve as a foundation for future special science courses and give one an appreciation of the content of these special sciences.

Motivation to Make Science a Part of the Pupil's Daily Life Activities.—One useful device in motivating the work is a score card. If the child is given a list of items for checking up the fire hazards in his home he is led to deal with real things in life. He and his parents will see the worth-while-

ness of his science work and defects discovered will lead, in many cases, to the application of the remedy. Other score cards, dealing with the environment, natural resources, fuels, lighting, foods, water supply, sanitation, health, insect pests, transportation facilities, labor saving devices, home grounds, recreation opportunities, safety devices, and educational opportunities to continue science study will help in a very marked way to show the pupil that his science is not merely useable in every day life, but he cannot live a rational childs life without using this very science that he is studying, and that science is an essential element in almost all home and community activities. As a result of discussing the score cards, numerous problems and projects will arise, often leading the pupil to undertake a project to improve some faulty condition which has been discovered, for example: such project work might result in better drainage around the homes; in removing some fire trap, such as a defective stove pipe; in greater economy in purchasing fuel; in installing an electric door-bell; in improving the lighting or decreasing its cost; in the removal of some menace to health; in the extermination of pests around the home; and in providing proper games to exercise one's muscles and mind.

The organization of science clubs in connection with the science classes and the substitution of club programs in part, or entirely, in place of ordinary class exercises, has, under proper leadership, proved very stimulating to the pupils. The reports of the club work done under the direction of Morris Meister of New York, of J. Richard Lunt of Boston, of Harry A. Carpenter of Rochester, and of Frank W. Murphy of Pittsburgh have led many other teachers to undertake it. The testimony now coming in is strongly in favor of this type of work.

Three suggestions, then, for motivating the work are the use of score cards, using the project method, and forming science clubs. These three may be used together.

Cyclic Method.—When we stop to think how many times we must do a thing over and over again before it becomes a habit we can better realize why it is that so much useful knowledge which once enters the child's mind is lost. It is the repeated stimulation of the same idea brought up now in one relation and then in another that makes the deep and lasting im-

pression. We can well apply this principle in our science teaching by adopting the cyclic method. Suppose we plan a two-year course in general science, the first year of which is to be in *Home Science* and the second year in *Community Science.* Early in the first year we make a survey of the science in the home environment. We touch on the high spots of many science problems but leave the details until later in the year. In the second year the majority of these science problems come up with increased significance. They are no longer individual problems, but many of the same science principles or facts associated with other principles and facts are applied in a larger field—to the community. Here again we may have an initial survey and later a detail study. Let me illustrate by reference to the problem of safe-guarding against fires: In our survey of science in the home, fire, particularly its usefulness will be mentioned and discussed but let us not leave the subject of fire until its harmfulness when uncontroled has been thoughtfully considered. In the first approach let the pupils pool their knowledge on "Fire Hazards in the Home" and "How to Extinguish Fires." Some additions may be made by the teacher. The chief purpose of this initial survey is to raise problems, to develop projects and thus open the way for vital individual work by the pupils. Later in the course the study of fire hazards, preventive measures, methods of extinguishing, etc. come up for detailed study. Then those who have matured projects upon these topics will report them in class. The next year in a survey of the science of the community the city fire-fighting outfit will never fail to be mentioned. In the survey the first week several projects may be started. Later on, the reports of these together with other assigned classwork will bring back the various principles and facts which underlie a good understanding of fires and fire-fighting. In working out projects the second year certain knowledge gained the first year is needed. If it has been forgotten the pupil, seeing the need of it, will seek that information voluntarily and because of its having been obtained to satisfy a need and because of its having been repeated it will be more permanent.

What Science can Contribute to Good Citizenship.—Very prominent among the aims of general science formulated by the N. E. A. Committee on the Reorganization of Secondary Education, are those which bear directly and indirectly upon good citizenship. The science must contribute to the pupil's individual needs and as well to the needs of the community of which he is a member. As contributions toward producing worthy citizens, it may be expected that general science will:

1. Satisfy personal desire for science knowledge and produce "well-informed" members of society.
2. Help eliminate superstition and fallacies which are a great hindrance to progress.
3. Develop imagination and create a vision of better ways and things.
4. Develop alertness to public questions by considering the science problems relating to community welfare.
5. Develop a habit of scientific thought or method of sound reasoning.

The time has passed when one is considered well educated if he can read a page of Latin, but cannot tell how the electric bell works. Science information upon common things is now considered essential to every member of society. Many questions of public importance involving knowledge of science must be settled by the public. Without a fundamental knowledge of the science involved in these questions, one is unable to reach any fair conclusion regarding the advisability of any proposed change. We still have with us people who "know" the weather is controlled by the moon. Science is the key which can unlock the door to free thousands of our citizens from the restraint of superstition and fallacies.

What is life without imagination? How can we expect improvement in an individual, in a community, or in the human race, without the ability to see a vision ahead? Beecher has said, "A soul without imagination would be like an observatory without a telescope." What subject offers better opportunities for exercise of imagination than science? One can hardly expect the average citizen to become interested in public questions of which he has no understanding. Scores of community science problems can be made so interesting to

boys and girls that the interest will not merely *live*, but *grow* with the years. The experimental methods of science, requiring as it does, the doing, the observation, the thinking and the drawing of conclusions warranted by observed data, is bound to produce a habit of sound reasoning. That every effect has a cause is no mere chance and for every act there must be some result. Science teaches truth and its application to ethics is clear. Science has much to contribute towards producing straight-thinking Americans, and thus it has great civic responsibility resting upon it. It is only necessary to recognize this responsibility and to fix the attention upon those science matters of civic importance in order that general science may make its contribution and discharge its obligation to society.

Atmospheric Phenomena [1]

W. J. HUMPHREYS, United States Weather Bureau.

Many curious and beautiful phenomena, of which the mirage, the rainbow, the halo, the azured sky, and the twilight glow, are some of the more conspicious, are due to the optical properties of the air and the foreign substances suspended in or falling through it. All, or nearly all, of them have been the objects of innumerable observations and many careful studies, the results of which, fortunately, have been summarized and discussed by various authors.

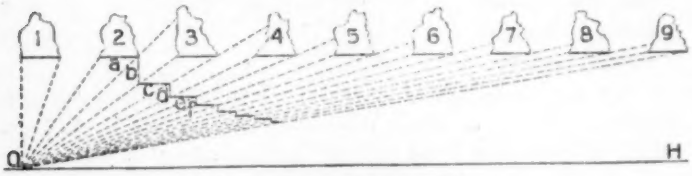
PERSPECTIVE PHENOMENA

Apparent Stair-step Ascent of Clouds.—The stair-step appearence of the echelon cloud is, perhaps, the simplest sky phenomenon due to perspective. The exact manner by which the stair-step or terrace illusion is brought about is shown by Fig. 1, in which O is the position of the observer, *H* his horizon, 1, 2, 3, etc, evenly spaced flat-bottomed cumuli of the same base elevation—flat bottomed and of constant level because of the approximately uniform horizontal distribution of moisture.

Since the clouds are at a higher level than the observer, each successive cumulus, as the distance increases, is seen at a lower angle than its predecessor; and the dark bases of any

[1] Extracts from article "Optics of the Air" in *Jo. of Franklin Institute*, Oct. 1919.

two adjacent clouds appear to be connected with each other by the lighter side of the farther one. Besides, their general resemblance to stair-steps often leads one into the error of "seeing" the connection between any two adjacent bases to be at right angles to both. That is, starting with *base a*, the light side of cloud 3 appears as a vertical surface at *b*, and its base as a dark horizontal surface at *c;* the side and base of cloud 4 appear as the next vertical and horizontal surfaces, *d* and *e*, respectively, and so on for the other clouds; the whole effect merging into the appearance of a great stairway, consisting of the horizontal treads, *a*, *c*, *e*, etc., connected by the seemingly vertical risers, *b*, *d*, *f*, etc.



1. Cloud echelon effect.

Apparent Arching of Cloud Bands.—Occasionally a narrow cloud band is seen to stretch almost, if not entirely, from horizon to horizon, but although its course is practically horizontal and its direction often nearly straight, it usually appears arched. If even the nearest portion of the cloud still is far away, the apparent arching is slight. On the other hand, when the cloud is near the arching is great. The apparent curve is neither circular nor elliptical, but resembles rather a conchoid whose origin is at the observer and whose asymptote is his horizon.

The angle of elevation at which different segments of the cloud are seen clearly varies from a minumum for the more distant portions to a maximum for the nearest. Hence, the phenomenon in question, the apparent arching of the band along its nearest portions, is only an optical illusion, due entirely to the projection of the cloud (above the observer's level) onto the sky.

When several such bands or streaks occur in parallel, they appear to start from a common point at or beyond the horizon, to terminate, if long enough, in a similar opposite point, and progressively to arch and spread apart as they approach the

observer's zenith. They thus form the perspective effect often called "Noah's Ark" or polar bands.

Apparent Divergence and Convergence of Crepuscular Rays (Sunbeams).—Everyone is familiar with the beautiful phenomenon of the "sun drawing water"—sunbeams, that, finding their way through rifts in the clouds, are rendered luminous by the dust in their courses. Equally familiar and equally beautiful are also those streaks and bands of pearly lights (where the lower atmosphere is illuminated) and azure shadows (where only the upper atmosphere is illuminated) that often at twilight and occasionally at dawn radiate far out from the region of the sun, and at times even converge towards the opposite point of the horizon. These, too, are only beams of sunlight and shadow caused by broken clouds or irregular horizon.

All such crepuscular rays, whether their common origin, the sun, be below or above the horizon, seems first to diverge, while the few that cross the sky appear also to arch on the way and finally to converge towards the antisolar point.

Here, again, the facts are not as they seem, for the rays, all coming, as they do, from the sun, some 93,000,000 miles away, necessarily are practically parallel. Their apparent divergence, convergence, and arching are all illusions due to perspective, just as are the apparent divergence, convergence, and arching of the rails on a long straight track.

Apparent Divergence of Auroral Streamers.—Anyone at all familiar with the appearence of auroral streamers will recall that at most localities they seem to radiate from some place far below the horizon. In reality they do diverge (or converge, if one prefers) slightly since they follow, approximately, the terrestrial lines of magnetic force. Indeed, their rate of convergence is about the same, on the average, as that of the geographic meridians at the same latitudes, and therefore far less than one would infer from their apparent courses. That is, their seeming rapid convergence is only another illusion due to perspective, just as is the apparent divergence of the crepuscular rays, as above explained.

Apparent Shape (Flat Vault) of the Sky.—To everyone the sky looks like a great blue dome, low and flattish, whose circular rim rests on the horizon and whose apex is directly overhead. So flat, indeed, does this dome appear to be that

points on it estimated to lie half-way between the rim and apex generally have an elevation of but little more than 20 degrees, instead of 45 degrees, as they would if it seemed spherical.

That the rim of the sky dome should appear circular is obvious enough. It is simply because the horizon, where land and sky come together, itself is circular, except when conspicuously broken by hills or mountains.

To understand the other and more important feature, that is, why the dome looks so flat, consider (1) a sky filled from horizon to horizon with high cirrus clouds. These seem nearest overhead for the simple reason that that is just where they are nearest. As the horizon is approached, the clouds merge, through perspective, into a uniform gray cover that appears to rest on the land at the limit of vision, whether this limit be fixed by the curvature of the earth or by haze, and the whole cloud canopy may seem arched just as and for the same reason that cloud streaks and crepuscular rays seem arched, as above explained. But (2) even a thin cirro-stratus veil whose parts are well-nigh indistinguishable produces a similar effect, the nearest portions appearing nearest, largely because they are the most clearly seen. Similarly, when there are no clouds the sky overhead also appears nearest because it is clearest; and that unconscious inference, based on endless experience, is correct—it is clearest because nearest. As the eye approaches the horizon, the increasing haze produces the impression of greater distance; and this impression is entirely correct, for the blue sky seen in any such direction is farther away than the sky overhead. In short, the spring of a cloudless sky dome is "seen" to rest on the distant horizon and its ceiling to come closer and closer, in proportion to increasing clearness, as the zenith is approached. The shape, then, of this dome should not always appear the same, and it does not—not the same on a clear night, for instance, as on a clear day.

Impressions, therefore, of the "shape" of the sky are, perhaps, not so erroneous as sometimes they are said to be. Indeed, they usually conform surprisingly well to the actual facts.

Change with Elevation, or Apparent Size of Sun and Moon.—One of the most familiar, as also one of the most puzzling,

of optical illusions is the change between the apparent sizes of the full moon, say, or of the sun, at rising or setting, and at or near culmination. It is, however, only a phenomenon of perspective.

Since the solid angle subtended at any place on the earth by the moon, as also that subtended by the sun, is sensibly constant throughout its course from rising to setting, it follows that its projection, and, therefore, its apparent size, must be relatively large, or small, as the place of projection (sky dome) is comparatively far away or nearby. But, as already explained, the sky dome, against which all celestial objects are projected and along which they therefore appear to move, seems to be farther away, and is farther away, near the horizon than at places of considerable elevation. Hence the moon and the sun must look much larger when near the horizon than when far up in the heavens, and the fact that they do look, is, as stated, merely a phenomenon of perspective.

The familiar fact that the moon appears of one size to one person and a different size to another clearly is also due to perspective. The one who judges it large imagines his comparison object to be at a greater distance than does the one who judges it small. Why two people, however, should differ so widely in their reference or comparison distances, as obviously they often do, is by no means clear.

Change, with Elevation, of Apparent Distance Between Neighboring Stars.—The generally recognized fact that the distance between neighboring stars appears much greater when they are near the horizon than when well up is also a phenomenon of perspective. Its expanation is identical with that of the change, under similar circumstances, of the apparent diameter of the moon, and therefore need not be given in further detail.

Scintillation or Twinkling and Unsteadiness of Stars.—The scintillation or twinkling of stars, that is, their rapid changes in brightness and occasionally also in color, especially when near the eastern or western horizon, is a well-known, and now well-understood, phenomenon that for many centuries, certainly since the days of Aristotle (384-322 B. C.), who noted the fact that the fixed stars twinkle while the planets shine

with comparatively steady lights, has been observed, investigated, and discussed.

Atmospheric inequalities produce "unsteadiness," or rapid changes in the apparent positions of the stars as seen in a telescope. In reality, this is a telescopic form of scintillation which, because never amounting to more than a very few seconds of arc, the unaided eye cannot detect. On the other hand, the great changes in brightness and color so conspicuous to the naked eye are scarcely if at all noticeable in a large telescope. This is because the object glass is so large that, in general, light deflected from one portion of it is caught in another.

Scintillation of the Planets, Sun, and Moon.—It is commonly stated that the planets do not scintillate—that the light from the several portions of their disks follow such different paths through the atmosphere that not all nor even any large portion of it can be affected at any one time. It is true that because of their sensible disks the scintillation of planets is much less than that of fixed stars, but under favorable circumstances their scintillation is quite perceptable. Even the rims of the sun and the moon boil or "scintillate" while, of course, any fine marking on either or on a planet is quite as unsteady as the image of a fixed star.

Nature of Irregularities.—It is well known that the atmosphere, generally, is so stratified that with increase of elevation many more or less abrupt changes occur in temperature, composition, density, and, therefore, refrangibility. As such layers glide over each other, billows are formed, and the adjacent layers thereby corrugated. The several layers frequently also heat unequally, largely because of disproportionate vapor contents, and thereby develop, both day and night, and at various levels, innumerable vertical convections; each moving mass differing, of course, in density from the surrounding air, and by the changing velocity being drawn out into dissolving filaments. Optically, therefore, the atmosphere is so heterogeneous that a sufficiently bright star shining through it would produce on the earth a somewhat streaky pattern of light and shade.

Shadow Bands.—A striking proof of the optical streakiness of the atmosphere is seen in the well-known shadow bands that at the time of a total solar eclipse appear immediately before the second, and after the third, contact.

Terrestrial Scintillation.—A bright terrestrial light of small size, such as an open electric arc, scintillates when seen at a great distance, quite as distinctly as do the stars and for substantially the same reason, that is, optical inequalities due to constant and innumerable vertical convections and conflicting winds.

Shimmering.—The tremulous appearance of objects, the common phenomen of shimmering, seen through the atmosphere immediately over any heated surface, is another manifestation of atmospheric refraction, and is due to the innumerable fibrous convections that always occur over such an area.

Optical Haze.—The frequent indistinctness of distant objects on warm days when the atmosphere is comparatively free from dust, and ascribed to optical haze, is due to the same thing, namely, optical heterogeneity of the atmosphere, that causes that unsteadiness or dancing of star images that so often interferes with the positional and other exact work of the astronomer. Both are but provoking manifestations of atmospheric refraction.

Times of Rising and Setting of Sun, Moon, and Stars.—An interesting and important result of astronomical refraction is the fact that the sun, moon, and stars rise earlier and set later than they otherwise would. For places at sea level the amount of elevation of celestial objects on the horizon averages an arc of about 35 minutes and therefore the entire solar and lunar disks may be seen before (on rising) and after (on setting) even their upper levels would have appeared, in the first case, or disappeared, in the second, if there had been no refraction. This difference in time of rising, or setting, depends on the angle or inclination of the path to the horizon.

The minimum time occurs when the path is normal to the horizon and is about 2 minutes 20 seconds, while the maximum, which obviously occurs at the poles, is infinite in the case of stars that just clear the horizon, and, for the sun, about a day and a half, the time required near equinox for the solar declination to change by 35 minutes.

Green Flash.—As the upper limb of the sun disappears in a clear sky below a distant horizon its last star-like point often is seen to change rapidly from pale yellow or orange to green and finally blue, at least, a bluish-green. The vividness of the green, when the sky is exceptionally clear, together with its almost instant appearance, has given rise to the name "green flash" for this phenomenon. The same gamut of colors, only in reverse order, occasionally is seen at sunrise.

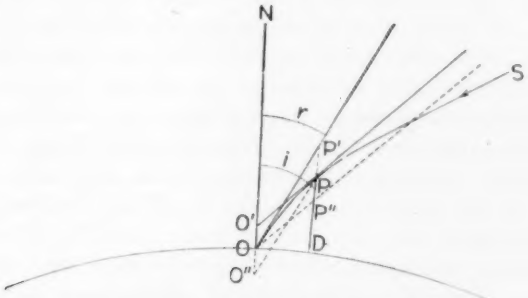
The entire phenomenon has been described by some as merely a complementary after-image effect, that is, the sensation of its complementary color that frequently follows the sudden removal of a bright light. This explanation, however, cannot account for the reverse order of the colors as seen at sunrise. Neither does it account for the twinkling of the "flash" close observation now and then reveals, nor for the fact that when the sun is especially red the "flash" is never seen.

It is not, indeed, a physiological effect, but only the inevitable result of atmospheric refraction, by virtue of which as a celestial object sinks below the horizon its light must disappear in the order of refrangibility; the red first, being least refrangible, then the green, and finally the blue or most refrangible. Violet need not be considered, since only a comparatively small portion of it can penetrate so far through the atmosphere.

It may properly be asked, then, why these color changes do not apply to the whole solar disk. The answer is, because the angular dispersion, due to the refraction of the atmosphere, between the several colors is very small—between red and green, for instance, only about 20 seconds, even when the object is on the horizon, so that any color from a given point on the sun is reinforced by its complementary color, thus giving white from a closely neighboring point. Hence, color phenomena can appear only when there are no such neighboring points, or when only a minute portion of the disk is above the horizon. It must further be noted that color effects, due to the general refraction of the atmosphere, occur only when the source (brilliant point) is on the horizon. Stars above the horizon are not permanently drawn out into rainbow bands, and that for the simple reason that the red light by one route is supplemented by the green, blue, etc., by others and the

whole blended into white, yellow, or whatever the real color of the star may be. This multiplicy of routes and consequent blending of color, is not possible for rays of light from objects just sinking below or rising above the horizon, and, therefore, under such circumstances, they pass through a series of color changes.

Terrestrial Refraction.—The curving of rays of light is not confined to those that come from some celestial object, but applies also to those that pass between any points within the atmosphere, whether at the same or different levels. This latter phenomenon, known as terrestrial refraction, causes all objects on the earth or in the atmosphere to appear to be at greater altitudes than they actually are, except when the surface air is so strongly heated as to cause an increase of density with elevation and thus produce the inferior mirage, described below.



2. **Approximate terrestrial refraction.**

Let *ON* (Fig. 2) be normal to the surface, *OD*, of the earth, and let *P* be observed from *O*. Obviously *P*, whose horizontal distance, *OD*, may be supposed known, will seem to be at *P'* and thus its apparent altitude greater than the actual by the distance *PP'*. From the angle *r*, the density of the air at the observer's position, *O*, and the approximately density at *P* (known from the approximately height of *P*) it is easy to draw *OP''* parallel to the tangent at *P* to the refraction curve, *SPO*. This gives *P''*, necessarily below *P*. Hence *P* lies somewhere between *P'* and *P''*.

A more exact determination could be had by drawing the curve of refraction, *OPS*, corresponding to the angle *r* and noting its intersection with the normal at *D*.

If the observer happens to be at *P*, the point *O* will appear elevated to *O'*. Clearly, however, from a knowledge of the angle *PO'N*, and the approximate densities at *P* and *O*, one may draw *PO''* parallel to *P'O*, and thus locate *O* somewhere between the two determined points *O'* and *O''*. Here, too, it would be more accurate to use the refraction curve, *SPO*.

Even initially horizontal rays normally curve down towards the surface of the earth, so that objects at the observer's own level, as well as those above and below it, appear elevated. To understand this phenomenon, consider a wave front normal to the surface of the earth and, consequently, moving horizontally. If, now, the density of the air at the place in question decreases with increase of elevation, as it nearly always does, the upper portion of the wave front will travel faster than the lower, and the path will be bent down towards the earth along a curve whose radius depends upon the rate of this density decrease.

Looming.—Since the extension of the actual beyond the geometrical horizon depends upon the density decrease of the atmosphere with increase of elevation, it follows than any change in the latter must produce a corresponding variation of the former. An increase, for instance, in the normal rate of decrease, such as often happens over water in middle to high latitudes, produces the phenomenon of looming, or the coming into sight of objects normally below the horizon. Similar changes in the rate of density decrease with increase of elevation also are common in valleys, but here looming, in the above sense, is rendered impossible by the surrounding hills or mountains.

Towering.—The condition of the atmosphere that produces looming, in the sense here used, or would produce it if the region were level, often gives rise to two other phenomena, namely, unwonted towering, also usually called looming, and the consequent apparent approach of surrounding objects.

The more rapid the downward curvature of the ray paths at the observer the more elevated, clearly, will objects appear to be, and such curvature may, indeed, be very considerable. Thus, a temperature inversion near the surface of the earth of 1 degree C. per metre change of elevation bends down a ray along an arc whose radius is about 0.16 that of the earth,

while an inversion of 10 degrees C. per metre—a possible condition through a shallow stratum—gives a radius of only about 0.016 that of the earth, or, say 100 kilometres. If now, as occasionally happens, the inversion layer is so located that rays to the observer from the top of an object are more curved than those from the bottom, it will appear not only elevated but also vertically magnified—it will tower and seem to draw nearer.

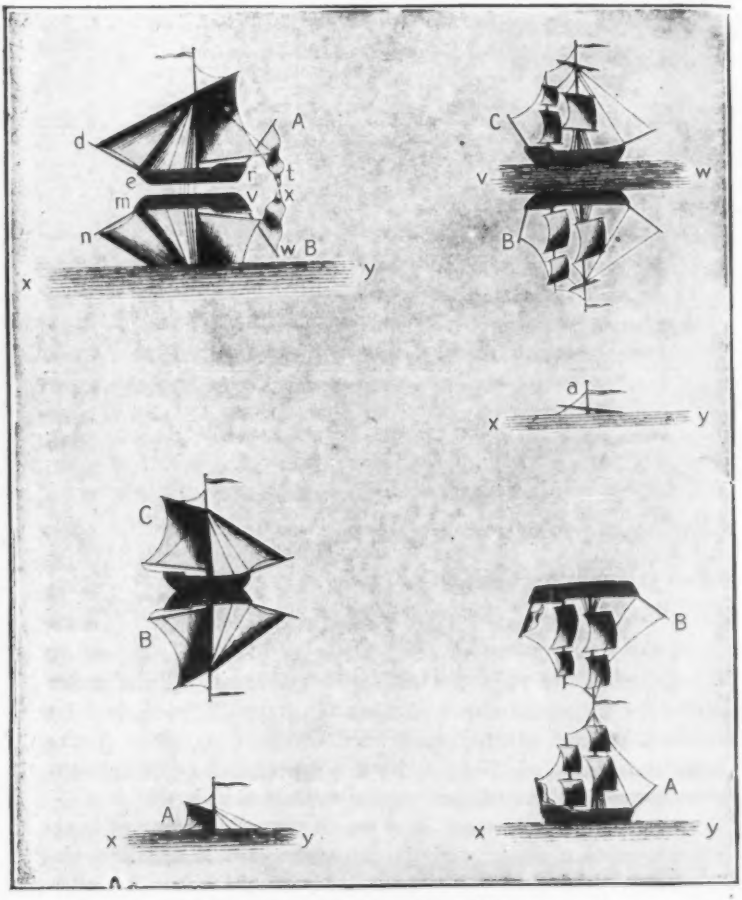
Sinking.—Instead of increasing the curvature of rays the temperature distribution may be such as, on the contrary, to decrease it and thereby cause objects normally on the horizon to sink quite beyond it. Such phenomena, exactly the reverse of looming, are also most frequent observed at sea.

Stooping.—Occasionally rays from the base of an object may be curved down much more rapidly than those from the top, with the obvious result of apparent vertical contraction, and the production of effects quite as odd and grotesque as those due to towering. Indeed, since the refraction of the atmosphere increases, in general, with the zenith distance, it is obvious that the bases of objects nearly always apparently are elevated more than their tops, and themselves, therefore vertically shortened. The normal effect, however, is small and seldom noticed except, perhaps, in connection with the slightly flattened shape of the sun and moon when on the horizon.

Superior Mirage.—It occasionally happens that one or more images of a distant object, a ship for instance, are seen directly above it, as shown in Fig. 3.

The mirage nearest the object always is inverted and therefore appears as though reflected from an overhead plane mirror—hence the name "superior mirage"—and, indeed, many seem to assume that this image really is due to a certain kind of reflection, that is, total reflection, such as occurs at the undersurface of water. It is obvious, however, that this assumption is entirely erroneous, since the atmosphere can never be sufficiently stratified in nature to produce the discontinuity in density (adjacent layers are always interdiffusible) this explanation of the origin of the proximate inverted image presupposes. Another apparently simple explanation of mirage phenomena is furnished by drawing imaginary rays from the

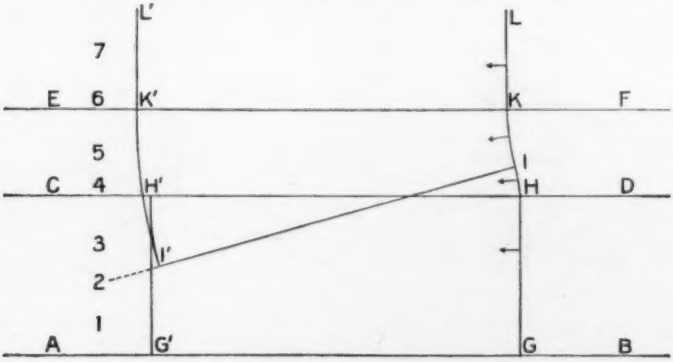
object along arbitrary paths to the observer. But, in reality, this is no explanation at all, unless it is first demonstrated that the rays must follow the paths assumed. It is allowable, of course to assume any *possible* distribution of atmospheric density and to trace the rays from an object accordingly. If the assumed distribution follows a simple law, the rays may be traced mathematically though such discussions, when at all thorough, necessarily are long.



Examples of superior mirage.

A simple explanation of mirage that admirably accounts for the phenomena observed has been given by Hastings,[1] in substance as follows:

Let the air be calm and let there be a strong temperature inversion some distance, 10 metres, say, above the surface—conditions that occasionally obtain, especially over quiet water. Obviously the ratio of decrease of density to increase of elevation is irregular in such an atmosphere, and therefore the velocity of light travelling horizontally through it must increase



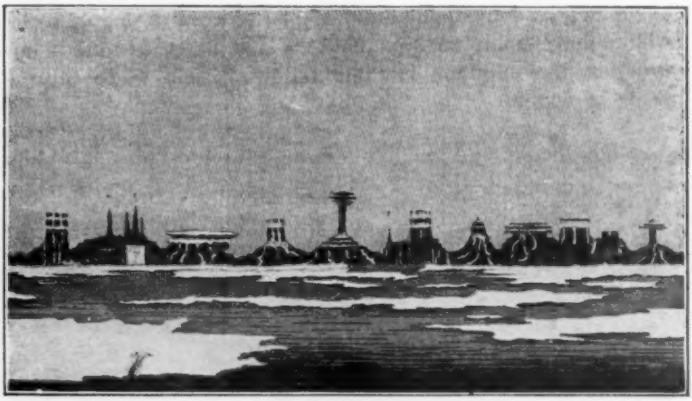
4. Wave fronts giving a superior mirage.

also irregularly with increase of elevation. Thus, beginning with the undersurface of the inversion layer, the rate of velocity increase with elevation must first grow to a maximum and then diminish to something like its normal small value at and beyond the upper surface of this layer. Hence, that portion of an orginally vertical, or approximately vertical, wave front that lies within the inversion layer must soon become doubly deflected, substantially as indicated in Fig. 4.

Let *AB* (Fig 4) be the surface of water, say, *CD* the under and *EF* the upper surface of a strong inversion layer, and let *GHIKL* be the distorted wave front of light, travelling in the direction indicated, from a distant source. The future approximate positions of the wave front, of which *G'H'I'K'L'* is one, are readily located from the fact that its progress is always normal to itself, and the appearance of the distant object from which these wave fronts are proceeding easily deter-

[1] "Light," Chapter 7, New York, Chas. Scribner's Sons, 1902.

mined. At 1, for instance, the object seems upright and at its proper level, no images are seen and the whole appearance is normal; at 2 confused elevated images appear, in addition to the object itself; at 3 the object and 2 distinct images are seen, the lower produced by the segment *HI* of the wave front inverted, the other erect; at 4, the under surface of the inversion layer, the inverted image blends with the object and disappears; at 5 only the erect image can be seen, and, indeed, may be seen even when the object itself normally would be below the horizon; at 6, the upper surface of the inversion layer, the vertical image merges with the object and disappears; while



5. Telescopic appearance of the coast of Greenland at the distance of 35 miles, when under the influence of an extraordinary refraction.

everywhere beyond the upper surface only the object itself is visable, as at 1, with no evidence whatever of abnormal refraction and mirage.

An additional inversion layer obviously might produce other images, while more or less confused layers might produce multiple and distorted images, such as shown in Fig. 5, copied from Scoresby's account of a certain telescopic view of the east coast of Greenland.

Inferior Mirage.—It is a very common thing in flat desert regions, especially during the warmer hours of the day, to see below distant objects and somewhat separated from them

their apparently mirrored images—the inferior image. The phenomenon closely simulates, even to the quivering of the images, the reflection by a quiet body of water of objects on the distant shore, the "water" being the image of the distant low sky, and therefore frequently leads to the false assumption that a lake or bay is close by. This type of mirage is very common on the west coast of Great Salt Lake. Indeed, on approaching this lake from the west one can often see the railway over which he has just passed apparently disappearing beneath a shimmering surface. It is also common over smooth-paved streets provided one's eyes are just above the street level. And under-grade crossing in a level town, for instance, offers an excellent opportunity almost any warm day of seeing well-defined small images that are apt to arouse one's surprise at the careless way his fellow-citizens wade through pools of water!

6. Wave fronts giving an inferior mirage.

Since the inferior mirage occurs only over approximately level places and there only when they are so strongly heated that for a short distance the density of the atmosphere increases with elevation it follows that its explanation is essentially the same as that of the superior mirage. Of course, the surface air is in unstable equilibrium and rising in innumeral filaments, but its rarefied state is maintained so long as there is an abundant supply of insolation. A wave front, therefore, from an object slightly above the general level soon becomes distorted through the greater speed of its lower portion, as schematically indicated in Fig. 6.

Let *AB* of this figure be the surface of the earth and *CD* the upper level of the superheated stratum. Let *EFG* be the position of a wave front travelling as indicated, the lower portion curved forward as a result of its greater speed in the rarefied layer. One of the consequent later positions of the wave front is shown at *E'F'G'*, from it follows that and

neither the object in question nor any image of it can be seen; at 2 the object and its inverted image are glimpsed, superimposed; at 3 both the object and its inverted image, well below it, are plainly visible; at 4 the image is just disappearing; while at 5 there is no evidence of a mirage, unless of objects more distant than the one under consideration.

Great uncertainty may exist, therefore, in regard to the exact positions of the objects seen in (or perhaps hidden by) a mirage. Thus, in his official report of the battle of April 11, 1917, between the English and the Turks in Mesopotamia, General Maude, the British commander, says: "The fighting had to be temporarily suspended owing to a mirage."

Lateral Mirage.—Vertical sheets of abnormally dense or abnormally rare atmosphere obviously would produce lateral mirages in every way like those due to similar horizontal layers, and indeed such mirages are occasionally seen along walls and cliffs whose temperatures differ widely from that of the air a few metres from them.

Fata Morgana.—Morgana (Breton equivalent of sea woman), according to Celtic legend and Arthurian romance, was a fairy, half-sister of King Arthur, who exhibited her powers by the mirage. Italian poets represent her as dwelling in a crystal palace beneath the waves. Hence, presumably, the name Fata Morgana (Italian for Morgan la Fay, or Morgan the fairy) was given, centuries ago, to those complicated mirages that occasionally appear over the strait of Messina moulding the bluffs and houses of the opposite shore into wondrous castles that alike tower into the sky and sink beneath the surface; nor is it strange that this poetical name should have become generic, as it has, for all such multiple mirages wherever they occur.

According to Forel, this phenomenon, to which he has given much attention, results from the coexistence of the temperature disturbances peculiar to both the inferior and superior mirgaes, such as might be produced by a strong inversion over a relatively warm sea. This, of course, implies a marked increase of density with elevation to a maximum a short distance above the surface, followed by a rapid density decrease —an unstable condition and therefore liable to quick and multiform changes. Obviously, too, such a cold intermediate layer

in addition to producing a double mirage acts also as a sort of cylindrical lens that vertically magnifies distant objects seen through it.

No wonder, then, that under such circumstances the most commonplace cliffs and cottages are converted, through their multiple, distorted, and magnified images, into magic castles, or the marvellous crystal palaces of Morgan le Fay!

REFRACTION PHENOMENA IN DROPS OF WATER

Principal Bows.—Rainbows differ among themselves as one tree from another, and besides some of their most interesting features usually are not even mentioned—and naturally so, for the "explanations" generally given of the rainbow may well be said to explain beautifully that which does not occur and to leave unexplained that which does.

The ordinary rainbow, seen on a sheet of water drops—rain or spray—is a group of circular or nearly circular arcs of colors whose common centre is on the line connecting the observer's eye with the exciting light (sun, moon, electric arc, etc.) or rather, except rarely, on that line extended in the direction of the observer's shadow. A very great number of rainbows are theoretically possible and doubtless all that are possible actually occur, though only three (not counting supernumeraries) certainly have been seen on sheets of rain. The most brilliant bow, known as the *primary*, with red outer border of about 42 degrees radius and blue to violet inner border, appears opposite the sun (or other adequate light); the next brightest, or the *secondary* bow, is on the same side of the observer, but the order of its colors is reversed and its radius, about 50 degrees to the red, is larger; the third or *tertiary* bow, having about the same radius as that of the primary and colors in the same order, lies between the observer and the sun, but is so faint that it is rarely seen in nature. Obviously the common centre of the primary and secondary bows is angularly as far below the observer as the source (sun generally) is above, so that usually less than a semi-circle of these spectral arcs is visible, and never more, except from an eminence.

The records of close observations of rainbows soon show that not even the colors are always the same; neither is the band of any color of constant angular width; nor the total breadth of the several colors at all uniform; similarly the

purity and brightness of the different colors are subject to large variations. The greatest contrast, perhaps, is between the sharply-defined brilliant rainbow of the retreating thunderstorm and that illy-defined faintly tinged bow that sometimes appears in a mist—the "white bow" or "fog bow."

All these differences depend essentially upon the size of the drops, and therefore inequalities often exist between even the several portions, especially top and bottoms, of the same bow, or develop as the rain progresses. Additional complications occasionally result from the reflection of bows and from bows produced by reflected images of the sun, but though unusual and thus likely to excite wonder and comment such phenomena are easily explained.

by reflected images of the sun, but though unusual and thus likely to excite wonder and comment such phenomena are easily explained.

Supernumerary Bows.—Rather narrow bands of color, essentially red, or red and green, often appear parallel to both the primary and the secondary bows, along the inner side of the first and outer of the second. These also differ greatly in purity and color, number visable, width, etc., not only between individual bows but also between the several parts of the same bow. No such colored arcs, however, occur between the principal bows; indeed, on the contrary, the general illumination here is perceptibly at a minumum.

Popular Questions about the Rainbow.—A few popular questions about the rainbow need perhaps to be answered. "What is the rainbow's distance?" In the sense of its proximate orgin, the drops that produce it, it is nearby or far away, according to their respective distances, and thus extends from the closest to the farthest illuminated drops along the elements of the rainbow cone. Indeed, the rainbow may be regarded as consisting of coaxial, hollow conical beams of light of different colors seen edgewise from the vertex and thus having great depth or extent in the line of sight.

Why is the rainbow so frequently seen during the summer and so seldom during winter?" Its formation requires the coexistence of rain and sunshine, a condition that often occurs during local convectional showers but rarely during a general cyclonic storm, and as the former are characteristic of summer

and the latter of winter, it follows that the occurence of the rainbow correspondingly varies with the seasons.

"Why are rainbows so rarely seen at noon?" As above explained, the centre of the rainbow's circle is angularly as far below the level of the observer as the sun is above it, hence no portion of the bow can be seen (except from an elevation) when its angular radius is less than the elevation of the sun above the horizon now, during summer, the rainbow season, the elevation of the sun at noon is nearly everywhere greater than 42 degrees, the angular radius of the primary bow, or even 51 degrees, the radius of the secondary bow. A rainbow at noon, therefore, is except for very high latitudes, an impossible summer phenomenon, and, of course, a rare winter one, for reasons given above, even where possible.

"Do two people ever see the same rainbow?" Theory teaches, and ordinary experience shows, that as the observer remains stationary or moves, so also, other things being equal, does his rainbow. If then, two observers initially close together should move in opposite directions, each would find his rainbow responding in the same sense as his shadow, and presently the positions and, therefore, the identity of the two bows would become unquestionably different from which it follows that as the eyes of two observers must always be separated by a greater or less distance their bows must also be correspondingly separated and different—different in the sense that they have different positions and are produced by different drops. In short, since the rainbow is a special distribution of colors (produced in a particular way) with reference to a definite point—the eye of the observer—and as no single distribution (other than uniform and infinite) can be the same for two separate points, it follows that two observers do not and cannot see the same rainbow.

"Can one see the same rainbow by reflection that he sees directly?" An object seen by reflection in a plane surface is seen by the same rays that but for the mirror would have focussed to a point on a line normal to it from the eye and as far back of it as the eye is in front. But, as just explained, the bows appropriate to two different points are produced by different drops; hence a bow seen by reflection is not the same as the one seen directly. Rainbows are occasionally seen reflected in smooth bodies of water.

Laboratory Suggestions

A Cylinder of Acetylene Furnishes Gas for a Substitute Bunsen Burner Where Other Gas Is Unavailable. Ev. Eng. Mag. p. 50. Apr. 1919.

A Vacuum Cleaner for Laboratory. Ev. Eng. Mag. p. 54. Apr. 1919.

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How to Soften Brass. Ev. Eng. Mag. p. 46. Apr. 1919.

A Power Jig-Saw. Ev. Eng. Mag. p. 50. Apr. 1919.

Practicable Chemical Laboratory Devices. El. Exp. p. 42. May 1919.

How to Loosen a Glass Stopper. Ev. Eng. Mag. p. 48. Oct. 1919.

A Handy Laboratory Wash Bottle. El. Exp. p. 538. Oct. 1919.

Removing a Cork from Inside a Bottle. Pop. Sc. Mo. p. 145. May 1920.

Moving Picture Films

The most comprehensive list of industrial pictures ever compiled has just been issued by the National Board of Review of Motion Pictures at 70 Fifth avenue, New York City. The catalog gives 791 titles grouped according to subject. There are, for instance, 65 films listed under the caption, "Autos;" 22 under "Dairy;" "Electricity," 30; "Food," 58; "Lumber," 17; "Machinery," 24; "Railroads," 64; "Steel and Iron," 24; "Welfare," 67; "Clothing (including hats, shoes, leather belts, weaving, gloves, hooks and eyes, and hosiery, under separate captions), 43.

The following phases of industry are also well represented in this motion picture list; asphalt, cement, coal, cotton and wool, explosives, fire-arms, leather, oil, packing-house, paint, paper, farm implements, road-building, silk, soap, steel and wire, and telephone. Still other subjects represented in this list are: abrasives, aeroplanes; adding machines; mimeographs, multigraphs, typewriters, cash registers; books, newspapers; farming, fertilizing, cattle raising; banking, business school, mail order business, insurance, salesmanship; vacuum cleaners, linoleums, hardware and tools, furniture; fountain pens; drugs, dentistry; gas, public utilities; stoves, wagons, wallpaper; laundry; pottery; rubber; lace-making, fashions, and a number of others.

This catalog is offered by the National Board in line with its policy to furnish information on motion pictures of special character. It is obtainable from the Board at 25 cents a copy, and gives the length of each picture and the distributor. Pictures owned by the industrial department of the International Y. M. C. A. The General Electric Company, as well as those handled by the educational departments of several of the regular film companies, are grouped respectively under the names of these distributors, the subject classifications, however, being maintained even in this grouping.

At the top of the list appears the name of the National Committee for Better Films in conjunction with that of the National

Board of Review, 70 Fifth avenue, New York City, and the Board's slogan, "Selection—Not Censorship—the Solution."

This catalog will prove of great value to industries, welfare workers, schools, colleges, manual training and visual instruction agencies, chambers of commerce, rotary clubs, and social groups. It adds much available motion picture material to the small amount now used in visual education.

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The farm tractor in 1920. Ill. F. Z. Hazlett, Sci. Amer, 123: 612. Dec. 18, 1920.

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Astronomical explanations of glacial period. F. J. B. Cordeiro, Sci. Amer. Mo. 2:197. November, 1920.

Dualistic theory of cosmogany. Ill. E Mile Belot. Sci. Amer. Mo. 2:292-9. December, 1920.

What are nebulae? Russell Sullivan. Sci. Amer. Mo. 2:299. December, 1920.

Has the earth's rotational period changed? I. M. Lewis. Sci. & Inv. 8:860. December, 1920.

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Thirteen billion suns living and dead. Ill. A. T. Moreux. Pop. Sci. Mo. 97:6:59. December, 1920.

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The latest rigid airship. Ev. Eng. Mag. 10:48. October, 1920.

A simple hand launched glider. Ill. H. C. Ellis. Ev. Eng. Mag. 10:54. October, 1920.

The air mail service. Ill. William Mitchell. Rev. of Rev. 62:625-632. December, 1920.

Our army's air service. Ill. William Mitchell. Rev. of Rev. 62:281-290. September, 1920.

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Falconry, the sport of kings. Ill. L. A. Fuertes. Nat. Geog. Mag. 38:429-460. December, 1920.

American birds of prey. Ill. Nat. Geog. Mag. 38:460-7. December, 1920.

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Blotches and flashes of which our dreams are made. Cur. Opin. 69:668. November, 1920

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Tapping the earth's heat. Ill. T. O'Conor Sloane. Sci. & Inv. 8:724. November, 1920.

IMPORTANT ANNOUNCEMENT

Our many friends among the Science teachers and administrative officers of the schools and colleges will be interested to learn that we have recently absorbed the Chemical, Physical, Botanical, Zoological, Agricultural, Physiographical and Bacteriological Apparatus business of the **C. H. Stoelting Company, 3047 Carroll Avenue, Chicago.**

This company was a pioneer in the development of educational scientific apparatus and has established for itself a high place in the regard of all users of such material. We feel sure that the acquisition of their lines will place us in a position to render a still larger service to our friends and we trust that we may inherit a large share of the good will enjoyed by the C. H. Stoelting Company for so many years.

The C. H. Stoelting Company will continue the manufacture and sale of their well-known line of highly specialized physiological and psychological apparatus.

We shall endeavor to justify the confidence of our old friends by the use of the facilities thus

acquired to furnish the best apparatus which can be made, at the lowest possible cost to the school, with a maximum of satisfactory service in delivery.

We trust that our new friends will soon become acquainted with the ideals upon which our entire organization is built and that by the extension to them of our "Cenco Service" we may merit their hearty approval and the continuance of their good will.

The stocks of Chemical, Physical, Botanical, Zoological, Agricultural, Physiographical and Bacteriological Apparatus of the C. H. Stoelting Company have been transferred to our building and all orders sent to them since the consummation of this transaction will be given prompt attention so that our new customers will suffer no inconvenience whatever because of the change.

May we be pardoned for again calling the attention of our friends, old and new, to the fact that we are to-day the largest manufacturer of scientific apparatus for educational institutions in this country and, so far as we know, in the world.

We want you to get to know us intimately. The building shown above is our home and the latch string is always out for you. Don't fail to pay us a visit whenever you happen to be in or near Chicago.

The symbol shown here is our trade-mark and we hope that it may come to mean to you what it has to us, a token of honest effort to give the best that we have or know for the promotion of better scientific instruction and greater scientific achievement.

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FOOD

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How much house for how much money. Ill. F. C. Brown. Coun. Life. 38:6:46-8. October, 1920.
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Where the petroleum goes. Ill J. M. Bird. Sci. Am. 123:3. July 3, 1920.

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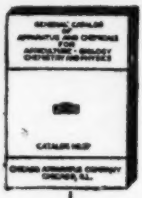

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Five years of the Panama Canal: an evaluation. Robert M. Brown. Geog. Rev. 9:191-8. March, 1920.

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The salt industry in China. Ill. Herbert T. Wade. Sci. Amer. Mo. 2:237-240. November, 1920.

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American City. The Tribune Building, N. Y. C. Monthly. $4.00 a year, 50c a copy. The science problems of city and rural communities are treated in numerous articles, well illustrated. A valuable student and teacher reference.

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General Science Quarterly. Salem, Mass. Quarterly. 40c a copy, $1.50 a year. The only journal published devoted alone to science in the elementary and secondary schools. It tells what schools are doing in science, gives lesson plans, demonstrations, and an extensive bibliography of usable articles in current periodicals.

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TOWN-PLANNING

Town-planning activities. Ill. G. F. Hayler. Rev. of Rev. 62:-633-7. December, 1920.

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Speeding up the traffic at world's busiest corner. Ill. H. Asbury and J. Brinker. Pop. Sci. Mo. 98:1:40. January, 1921.

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National Geographic Magazine. Washington, D. C. Monthly. 50c a copy, $4.50 a year. Best monthly journal for high grade pictures. Articles are of interest to general reader, pupils and teachers, as well as to geographers.

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Wood in the toy industry. Ill. Hu. Maxwell. Amer. For. 26:-731. December, 1920.

Uses: wood for musical instruments. Ill. Hu Maxwell. Am. For. 26:532-539. Sept. 1920.

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Wireless half-way Round the World. Ill. J. W. Kean. Sci. Am. 122:698. June 26, 1920.

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Yeast as food and medicine. Lit. Dig. 67:4:28. Oct. 23, 1920.

ZINC

Hydroelectric productions of zinc. Ill. World. 34:670. December, 1920.

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